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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Method and Apparatus for Producing Cellular Metal

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Notice: This application is as filed and may therefore contain an
incomplete specification.

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The present invention relates to a method and an apparatus for producing a cellular metal.

5 A method for producing a cellular metal is described in WO 91/03578. According to the disclosed method, a gas lance is arranged in a molten metal and its open end is partially closed by a disk-like covering element in such a way that a radial exit gap for the introduced gas is formed between the covering element and the body of the gas lance. As a result, the gas passes radially outwards from the lance, 10 whilst rotation of the gas lance produces turbulence, and a good permeation of the molten metal by the gas must be ensured. On the surface of the metal bath, above the gas exit opening of the gas lance, a skimming-off area for the cellular metal is disposed, so that a conveyor belt connected to the 15 skimming-off area can remove the formed cellular metals as a relatively flat layer.

A disadvantage of this method is that the thickness of the cellular metal layer varies very significantly, and the homogeneity of the cellular aluminium layer and also the size 20 of the enclosed gas bubbles are not completely satisfactory in terms of a desired narrow distribution of the gas bubble size.

An object of the present invention is therefore to provide a method and an apparatus for producing a cellular 25 metal, so as to permit the production of a highly homogeneous cellular metal body with a precisely defined profile.

According to an aspect of the present invention, there is provided a method for producing a cellular metal, said method comprising the steps of: heating a foamable 30 metal or a foamable metal alloy to produce molten metal or metal alloy; introducing the molten metal into a channel having a predetermined cross-section; supplying a gas or a gaseous mixture to the molten metal within said channel so as to form cellular metal within said channel; and discharging 35 the cellular metal from said channel.

According to another aspect of the present invention, there is provided an apparatus for producing a

cellular metal by means of the method according to the above-described method, said apparatus comprising a mould; an elongated channel disposed in the mould and having a predetermined cross-section defined by axial walls, one end of said channel defining a supply opening for a molten metal, and another end of said channel defining a discharge opening for cellular metal; and a gas supply means having at least one gas nozzle disposed in the channel for permeating molten metal in the channel with a gas or a gaseous mixture resulting in formation of cellular metal.

According to the present invention the foaming process is performed in a conduit or channel having a precisely defined cross-section. The cellular metal body passing out of said channel consequently has a profile which precisely corresponds to the profile forced onto the cellular metal body by the channel profile.

In this way it is possible to produce not only planar cellular metal layers with any desired thickness, but also e.g. wavy or zig-zag cellular metal profile strands.

The channel is preferably constructed in a shaping tool or mould, which is adapted to use interchangeable nozzles or mouthpieces, so that mouthpieces having different channel profiles can be used with the same shaping tool or mould. The mouthpiece has the channel section located above the molten metal/cellular metal phase boundary, which is predetermined by the molten metal level in the channel. The channel can be horizontal, inclined or vertical.

According to an advantageous further embodiment of the invention, the channel has a horizontal construction in the vicinity of the supply and removal opening. A vertical channel section, which contains the gas supply for forming the cellular metal, is provided between the two horizontal sections. The transitions between horizontal and vertical channel sections are preferably constructed in a continuously curved manner, which avoids the formation of sharp edges in

the channel, at which the gas bubbles would settle or turbulence in the molten metal could occur.

5 The molten metal can be of all metal types which are suitable for foaming, such as, for example aluminium, steel, zinc, lead, nickel, magnesium, copper and alloys thereof.

10 The metal can also be a metal matrix composite containing stabilizing particles of refractory material, e.g. silicon carbide or alumina. The metal matrix composite (MMC) can either be new material being melted for the first time, or alternatively remelted as a recycled material.

15 The size and gas distribution of the gas bubbles present in the cellular metal are controlled by means of the molten metal supply rate, the gas and possibly the content of stabilizing particles or viscosity-influencing impurities.

20 The gas supply is preferably located in the lower region of the vertical channel section, the level of the molten metal formed by the phase boundary between the molten metal and the cellular metal being at a level of 150 to 500 mm, preferably 300 mm above the gas supply. This molten metal level can be adjusted, for example, by means of a float control in a compensating chamber positioned parallel to the vertical channel section.

25 The gas supply mechanism preferably contains a gas supply comprising one or more gas jets or nozzles. In order to achieve a homogeneous distribution of the gas bubbles over the entire channel cross-section, it is possible to provide a nozzle array, for example in the form of a nozzle comb. This nozzle comb or sieve can further be moved in oscillating manner in order to prevent the formation of large gas bubbles. Oscillation of the nozzle comb also reduces the gas bubble size distribution, which is desirable for mechanical stability reasons, because very large gas bubbles impair the mechanical stability of the cellular metal in the vicinity of the bubble. A narrower size distribution of the closed gas bubbles leads to a greater homogeneity of the cellular metal body and

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therefore to more uniform physical (and in particular mechanical, acoustic and electrical) properties.

5 Instead of using a gas supply with several gas exit openings, it is also possible to use a single gas supply with a single gas exit opening, which is constructed as a divergent nozzle. A propeller-like stirrer can be positioned above the gas exit opening or above the nozzle, in order to very uniformly distribute the gas in the channel, and by simultaneously thoroughly mixing the gas bubbles with the
10 molten metal, bring about an additional homogenizing effect.

In a constructionally very simple and inexpensive further embodiment of the invention, the gas supply is constructed in the lower or bottom region of the vertical or inclined channel section in the form of a porous brick or a
15 porous sintered plate.

A further gas bubble size homogenization can be achieved if the gas is blown in intermittently. For this purpose the gas supply mechanism in the area just upstream of the gas exit opening is provided with a mechanical chopper,
20 which mechanically chops the gas inflow. As a result of the limited distance between the chopper and the gas exit opening of the gas supply, there are no natural vibrations of the air column.

The shaping tool or mould in which the channel is
25 located is preferably temperature-controlled in order to create clearly defined conditions during cellular metal formation. The mouthpiece (with different channel profiles) is preferably fitted just above the molten metal level, so that the cellular metal is preshaped to the desired profile
30 immediately following its formation. This prevents damage to closed gas bubbles during a subsequent deformation of the cellular metal body.

The foam-forming gas can be air, carbon dioxide, oxygen, water vapour, hydrogen or noble gases and mixtures
35 thereof.

If there is only a horizontal channel in the mould, and the gas supply takes place in the horizontal channel section, the gas exit openings of the gas supply are preferably constructed as sloping pipes projecting into the bottom region of the channel, so that the entire channel cross-section is uniformly permeated with gas bubbles. As a result of the buoyancy of the gas bubbles, preference is given to the provision of a curved or vertical channel section. The speed of cellular metal production can be regulated by the supply rate of the molten metal and the gas.

According to an advantageous further embodiment of the invention, the discharge rate of the cellular foam passing out of the channel can be regulated (for example by pulleys or rollers engaging on the cellular metal body) largely independently of the supply rate of the molten metal and the gas. As a result it is possible to, for example, apply a counterpressure to the cellular metal passing out of the mould, which leads to a limited compression of said cellular metal and therefore to an increase in the cross-section and a texture at right angles to the exit direction.

Preferably the mouthpiece is cooled in the vicinity of the channel discharge opening, so that the cellular metal body passing out is already rigid. In addition thereto, the cross-section of the channel to the discharge opening can be somewhat reduced, in order to compensate the shrinkage occurring during cooling. By tapering the channel cross-section to the discharge opening, it is also possible to subsequently regulate within certain limits the thickness of the cellular metal body passing out.

The apparatus for producing the cellular metal is characterized in that it not only permits the production of cellular metal bodies having clearly defined dimensions, but also in that it only has small dimensions as compared with conventional apparatuses.

In place of a gas supply mechanism, it is also possible to provide devices for the continuous supply of wire

in the gas supply area of the channel. Upon introduction to the channel, the wire disintegrates in the molten metal and splits off gas. In place of the wire it is also possible to introduce substances splitting off gas in other forms.

5 The invention is described in greater detail hereinafter relative to non-limitative embodiments and the attached drawings, in which:

 Figure 1 shows a lateral section through an apparatus for producing a cellular metal according to the present invention;

10 Figure 2 shows a second embodiment of an apparatus for producing a cellular metal according to the present invention, with a horizontally positioned channel;

 Figure 3 shows a third embodiment of an apparatus for producing a cellular metal according to the present invention, with an upwardly inclined channel;

15 Figure 4 illustrates an embodiment of a gas nozzle employed in the apparatus of Figure 1;

 Figures 5 and 6 show respective mouthpieces employed in the present invention, as viewed in the direction of arrow V of Figure 1.

20 Figure 1 illustrates a cross-section through an apparatus 10 for producing a cellular metal, comprising a channel 14 formed in a mould 12. Considered in a molten metal flow direction A, said channel comprises a first horizontal section 16, a vertical section 18 and a second horizontal section 20 connected thereto.

 The first horizontal section 16 of the channel 14 contains a supply opening 22 for a molten metal. The molten metal passes from the first horizontal section 16 into the vertical section 18, in whose bottom region is located a gas supply mechanism 24. The gas supply mechanism 24 has a gas supply 26 with a plurality of small nozzles in the manner of a nozzle comb. The gas supply 26 is moved in oscillating manner in the direction of the arrow B. By means of a

pressure regulator 28 it is possible to regulate the gas pressure at the gas supply.

5 The molten metal level 30 is set at a level h above the bottom region of the vertical channel section 18 by a suitable regulating device (not shown), such as a float mechanism in a parallel compensating chamber. This height h is preferably between 150 and 500 mm and is preferably 300 mm.

10 The upper part of the vertical channel section 18 and the second horizontal channel section 20 are formed within a mouthpiece 32, which is interchangeably secured in the mould 12. The mouthpiece 32 contains that part of the channel which is located above the molten metal level 30. The profile of the second horizontal channel 20 in the mouthpiece 32 can be varied as illustrated in Figures 5 and 6.

15 The molten metal level 30 forms the molten metal/cellular metal phase boundary. The cellular metal located above the level 30 passes out of the mould 12 through the discharge opening 34 and passes onto a conveying means provided with driving pulleys 36. The discharge opening 34 can, for example, have a width of approximately 2000 mm and a height of 200 mm.

20 The speed of the cellular metal body passing out of the apparatus 10 is essentially set by the molten metal supply rate and the gas supply rate. However, the speed can be additionally regulated by the discharge speed, which can be adjusted by the driving pulleys 36. In this way a slight counterpressure can be applied to the cellular metal, which brings about a certain compression and therefore a texture at right angles to the discharge direction.

25 The transition area between the channel sections 16, 18 and 20 is continuously curved, preferably being in the form of a partial radius, in order to prevent turbulence and the deposition of gas bubbles at the corresponding edges.

30 Figure 2 shows another embodiment of an apparatus 40 for producing a cellular metal. This apparatus 40 differs from the apparatus 10 of Figure 1 in that the channel 44

located in the mould 42 is horizontal over its entire length. The gas supply mechanism 46 contains a gas discharge nozzle 48, which discharges gas into the bottom region of the channel 44, so as to homogeneously permeate the entire area of the channel with gas bubbles. The gas discharge nozzle 48 can be constructed in such a way that the gas jet passing out is divergent. The mould 42, like the mould 12 in Figure 1, has a mouthpiece 43, which can have different profiles, such as is shown in Figures 5 and 6, for example.

Figure 3 shows another apparatus 50 for producing a cellular metal. The apparatus 50 contains a mould 52 with a mouthpiece 53 and a channel 54 having three sections. The channel 54 comprises a first horizontal section 56, an upwardly inclined, second section 58 connected thereto and which is in turn followed by a horizontal third section 60.

A gas supply mechanism 62 is located in the bottom region at the start of the second, inclined channel section 58. As in the apparatus of Figure 1, the molten metal/cellular metal phase boundary is located in the second, inclined channel section 52.

Although the best homogeneity of the cellular metal formed is to be expected in the apparatus of Figure 1, the use of the apparatuses of Figs. 2 and 3 can be advantageous, particularly if there is only a limited overall height available for the structure of the apparatus.

Obviously the supply and discharge openings of the channels can also be positioned vertically or inclined, so that connection is possible to associated equipment, for example, for producing a molten metal.

Figure 4 shows the upper part of a gas supply mechanism in the bottom region of a vertical channel section. The gas supply illustrated comprises a gas exit opening 70 in the form of a nozzle with a constriction.

Above the gas exit opening 70 can be positioned a propeller-like stirrer 72, which produces not only a turbulence of the gas bubbles present in the channel 74, but

also turbulence of the molten metal. As an alternative, or in addition thereto, a propeller-like mechanical chopper 76 can be provided below the gas exit opening 70, which facilitates the production of an intermittent gas jet. This
5 chopper 76 is preferably positioned as closely as possible below the gas exit opening 70, in order to prevent oscillation and resonance phenomena of the gas column located above the chopper.

Figures 5 and 6 show different embodiments of
10 mouthpieces 80,82, such as can be used in place of the mouthpiece 32 in the mould 12 of Figure 1. The mouthpieces 80,82 are shown as viewed in the direction of arrow V in Figure 1. Apart from mouthpieces for producing planar shaped parts or mouldings or zig-zag profiled shaped parts or
15 mouldings, it is also possible to produce all shapes which can be produced in conventional extrusion processes, for example corrugated or beaded profiles.

The present invention is suitable for the production of cellular metals made from all metals which can be foamed.
20 Preferably the method can be used for foaming new or recycled aluminium, independently of further alloying constituents or impurities.

It is possible to control different foaming
behaviour characteristics of recycled aluminum alloys by a
25 different method control, for example by controlling the gas supply and the molten metal supply in conjunction with a control of mechanical stirrers. In addition, to a certain extent it is possible to regulate the foaming behaviour by means of the temperature control of the mould 12, including
30 the mouthpiece 32.

The third, horizontal channel section 20 in the
mouthpiece 32 can be constructed as a cooling section for the cellular metal formed, so that the cellular metal passes out
of the mould at the removal opening 34 in a substantially
35 solid state. The cross-section of the channel 20 can be tapered towards the removal opening 34.

5 It is finally to be understood that although preferred embodiments of the present invention have been described, various other embodiments and variations may occur to those skilled in the art which fall within the scope and spirit of the invention, and such other embodiments and variations are intended to be covered by the following claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for producing a cellular metal, said method comprising the steps of:

heating a foamable metal or a foamable metal alloy to produce molten metal or metal alloy;

introducing the molten metal into a channel having a predetermined cross-section;

supplying a gas or a gaseous mixture to the molten metal within said channel so as to form cellular metal within said channel; and

discharging the cellular metal from said channel.

2. A method according to claim 1, wherein the gas is intermittently supplied to the molten metal.

3. A method according to claim 1, wherein a gas supply having a plurality of gas nozzles is located in the channel, said gas supply being moved in an oscillating manner during the gas supplying process.

4. A method according to claim 1, wherein the molten metal level is regulated to a fixed height with respect to the channel.

5. A method according to claim 4, wherein a float chamber is used to regulate the height of molten metal within the channel.

6. A method according to claim 4, wherein the level of molten metal within the channel is set at a height h of between 150 mm and 500 mm above the point at which gas is supplied to the molten metal.

7. An apparatus for producing a cellular metal by means of the method according to any one of claims 1 through 6, said apparatus comprising:

a mould;

an elongated channel disposed in the mould and having a predetermined cross-section defined by axial walls, one end of said channel defining a supply opening for a molten metal, and another end of said channel defining a discharge opening for cellular metal; and

a gas supply means having at least one gas nozzle disposed in the channel for permeating molten metal in the channel with a gas or a gaseous mixture resulting in formation of cellular metal.

8. An apparatus according to claim 7, wherein the channel has a substantially vertical portion.

9. An apparatus according to claim 8, further including regulating means for setting the level of the molten metal in the vertical portion of the channel.

10. An apparatus according to claim 8, whereby the vertical portion of the channel is disposed between two generally horizontal sections.

11. An apparatus according to claim 8, whereby the gas supply means is disposed in the bottom region of the vertical portion of the channel.

12. An apparatus according to claim 7, whereby the gas supply means is provided in the form of a nozzle comb or sieve having a plurality gas exit openings.

13. An apparatus according to claim 7, further including drive means adapted to cause oscillatory motion of the gas supply means.

14. An apparatus according to claim 7, wherein the gas supply means comprises a gas permeable porous brick or sintered member.

15. An apparatus according to claim 7, wherein a mechanical chopper for producing an intermittent gas flow is disposed just upstream of the gas exit opening of the gas supply means.

16. An apparatus according to claim 7, further including temperature control means for controlling the temperature of at least a portion of the mould.

17. An apparatus according to claim 7, wherein the mould is adapted for receiving an interchangeable mouthpiece including a respective channel portion and discharge opening having a particular cross-section, whereby the cross-section of the discharge opening of said channel can be selectively changed by installing a mouthpiece having a discharge opening of the desired cross-section.

18. An apparatus according to claim 17, wherein the mouthpiece contains the channel portion above the molten metal level.

19. An apparatus according to claim 7, wherein the cross-section of the channel tapers towards the discharge opening.

20. An apparatus according to claim 7, further including a propeller-like stirrer disposed above a gas exit opening of the gas supply means.

21. An apparatus according to claim 20, wherein the stirrer speed is regulatable.

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22. An apparatus according to claim 7, wherein a gas exit opening of the gas supply means is constructed as a gas nozzle for producing a divergent gas jet.

23. An apparatus according to claim 7, wherein the gas supply means contains means for the continuous introduction of a material which disintegrates in the molten metal, the disintegration being accompanied by gas formation.

24. An apparatus according to claim 23, wherein the disintegrating material is constructed as a wire electrode.

25. An apparatus according to claim 7, further including means disposed downstream of the discharge opening of the channel, for controlling the discharge speed of the solidifying cellular metal body from the discharge opening of the channel.

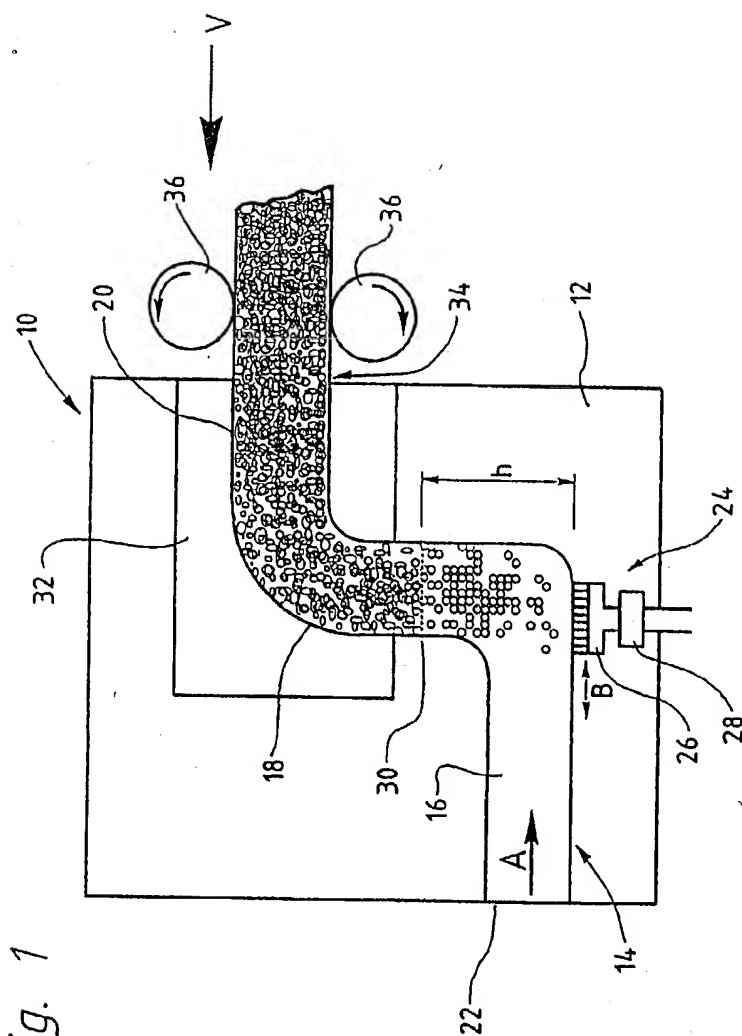


Fig. 2

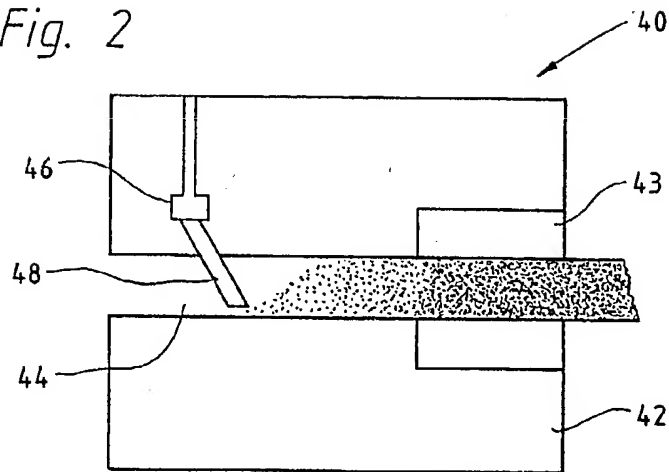


Fig. 3

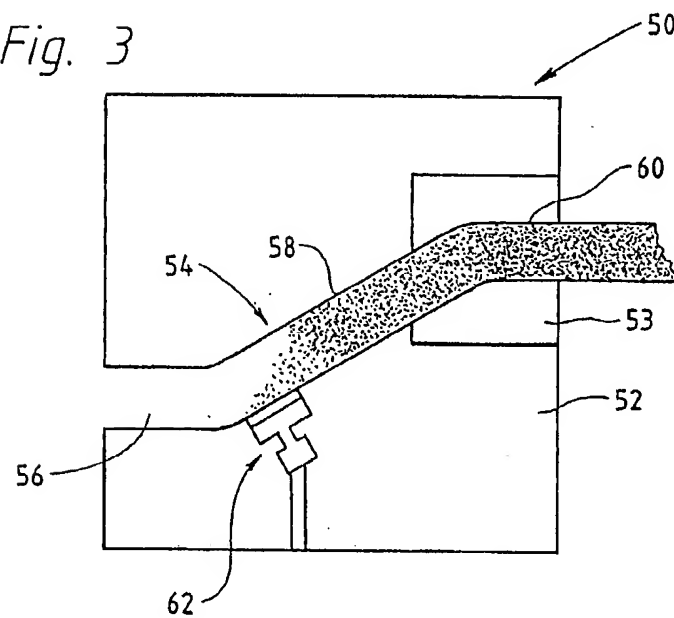
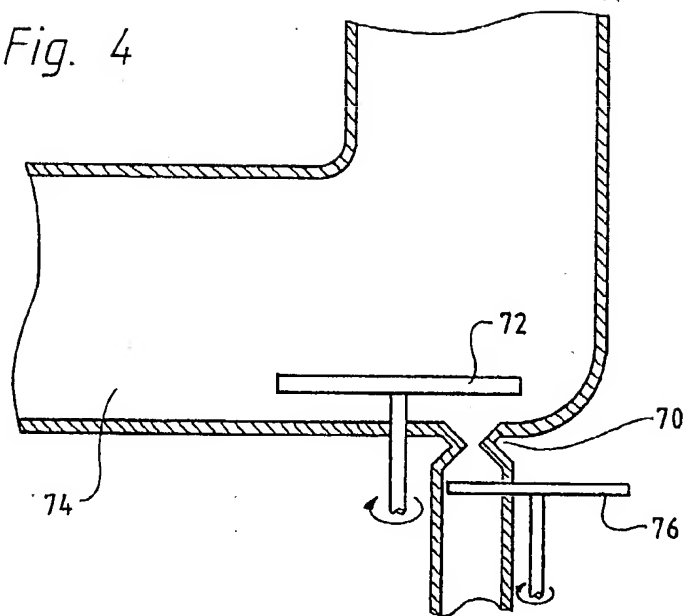


Fig. 4



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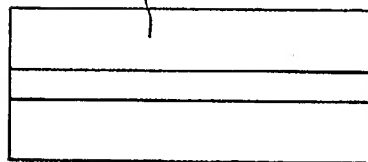


Fig. 5

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Fig. 6